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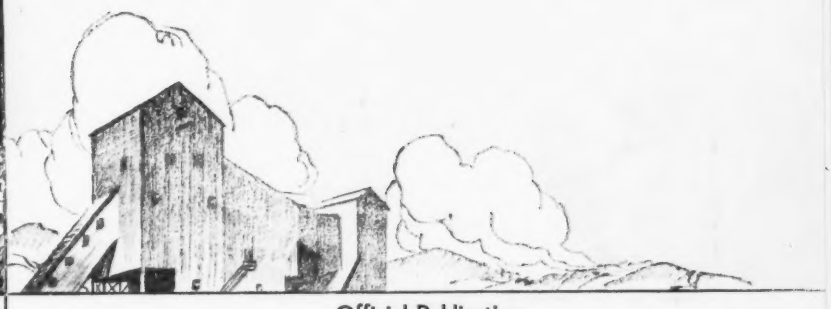
A Program Exceptional in Character Awaits You in Cincinnati

T. I. Weston—In Memoriam

Designing Concrete Mixtures for Pavements

The 1941 Construction Market



November—December · 1940

Official Publication
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The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

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Netherland Plaza Hotel
Cincinnati, Ohio

Convention Hotel
of the
24th Annual Meeting

THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XV No. 5 NOVEMBER-DECEMBER, 1940

A Program Exceptional in Character Awaits You in Cincinnati

IN KEEPING with the rapid march of events involved in the Nation's preparedness effort, the program for the 24th Annual Convention of the National Crushed Stone Association, to be held at the Netherland Plaza Hotel, Cincinnati, Ohio, on January 20, 21, and 22, offers the utmost in interest and value to members of the crushed stone industry. As desirable as it is under normal circumstances for members of an industry to act in concert with regard to matters effecting their common interest, to do so becomes doubly important when both industries and individuals must effectively contribute their full share in building the Nation's defenses adequate to turn back the threat from overseas. Bold indeed would be the prophet who could at this time forecast with any degree of certainty how the preparedness program will effect the crushed stone industry. Yet, if we are to coordinate our efforts with those of others and render the greatest service of which we are capable, nothing transcends in importance the consideration of such matters. The Annual Convention, bringing together as it does crushed stone producers from all sections of the United States, offers the one opportunity throughout the year for joint consideration of mutual problems. Such an opportunity carries with it a very definite and real responsibility—the responsibility of leaving our desks, our individual jobs, for the brief time required to attend this highly important meeting. It is our firm conviction that the program which gives full recognition to problems peculiar to crushed stone producers and at the same time has been developed with due consideration to topics of concern to all industry will meet with the wholehearted and enthusiastic approval. Without exception each topic scheduled for discussion has met the acid test of timeliness, informative value and interest and will be presented by a capable and authoritatively informed speaker.

To salesmen and operating men we wish to direct an especial appeal to attend as, departing somewhat from the practice of recent years, there will be held concurrent group sessions for salesmen and operating men, which will be devoted exclusively to a discussion of timely topics of particular interest to these groups.

A good barometer of convention interest is always indicated by the advance sale of booth space for the Manufacturers' Division Exposition, held in conjunction with the annual meeting. To date thirty-eight companies have contracted for space with the unusual and highly gratifying situation confronting us that only two booths remain available. This represents substantial improvement over last year and foreshadows an exceptionally well attended convention.

The following briefly outlines some of the more important highlights of the meeting. The final program in full detail will be sent out immediately after the first of the year.

Following the call to order by President Rigg at the opening session on Monday morning, January 20, a report will be made on business conditions during 1940 and the outlook for 1941. These reports as in the past will be prepared by the respective regional vice-presidents, but in order to conserve time on the convention program, President Rigg will incorporate them into a single summary. Reports will then be received from the Engineering Director and the Administrative Director, following which statements will be made concerning the present status of the determination of prevailing minimum wages for the crushed stone industry and with regard to seasonal exemption for the northern branch of the crushed stone industry. Stirling Tomkins will report on the former on behalf of the Executive Committee, and Otho M. Graves will report on the latter on behalf of the Executive Committee.

Efforts are being made to have the morning session conclude with a discussion of "Extensions and Use of Priorities," by a representative of the National Defense Commission. No one whose memory goes back to the World War can fail to recognize the extreme importance of this subject to our industry. Rapid developments in this connection seem certain to take place between now and the convention, which should make this talk of outstanding interest.

The eyes of the Nation are more and more upon Washington as the focal point of the defense effort and our speaker for the Greeting Luncheon on Monday is certain to command our interested attention when he talks on the intriguing subject, "The News Behind the News in Washington." We are especially fortunate in having obtained for this assignment Ray Tucker, widely known throughout the Natior for his column, "The National Whirligig," appearing daily in 2300 newspapers.

The Monday afternoon session will open with a talk by Roy W. Crum, Director of the Highway Research Board, Washington, D. C., entitled, "The Importance of Research to the Crushed Stone Industry." Mr. Crum will be followed by A. M. Philleo, Resident Engineer, Corps of Engineers, U. S. Army, Denison Dam, Denison, Texas, speaking on the subject, "Concrete for Outlet Works, Denison Dam." We will then hear John C. Gall, Counsel, National Association of Manufacturers, whom we are again most fortunate to have on our program, inform us concerning "Federal Legislation Effecting the Crushed Stone Industry." Ample time will be allowed for discussion following Mr. Gall's remarks, giving those present an excellent opportunity to have clarified any points concerning the application or administration of Federal laws with relation to our industry. As the concluding paper, Samuel W. Marshall, Chief Engineer of the Pennsylvania Turnpike Commission, will give us a talk illustrated by moving pictures dealing with the actual operation of the Pennsylvania Turnpike. As this is America's first large scale experiment in the field of superhighways, we will in effect be seeing a preview of the highways of tomorrow.

At six-thirty on Monday evening all persons at the convention will gather for an informal reception and buffet supper which will be followed at eight o'clock by the formal opening of the Manufacturers' Exposition.

In view of the greatly stimulated construction of airports in connection with defense plans, a paper entitled, "Asphaltic-Stone Construction for Airport Surfaces," which will open the Tuesday morning session, should prove of decided interest. We are unable to give the author of the paper at this writing as negotiations have not as yet been finally completed. Discussion of this paper will be led by A. M. Miller, Assistant Materials Engineer, West Virginia.

Relations between employers and employees continues to hold front rank position and we are fortunate indeed to have one of the outstanding authorities on this subject, C. S. Ching, Director of Industrial and Public Relations of the U. S. Rubber Company, discuss for us "Present Day Industrial Relations."

Hand in hand with any consideration of airport construction goes "Mechanical Stabilization of Subgrades and Bases," a topic to be presented by C. A. Hogentogler and Harold Allen of the Public Roads Administration, both experts in this field.

The Tuesday morning session will be concluded with the report of the Nominating Committee, the election of officers and the greeting of the president-elect. Though customarily the election of officers has taken place on Wednesday afternoon, when it was decided to have concurrent group sessions for salesmen and operating men on the afternoon of that day, it seemed advisable in order to give those groups sufficient time for an adequate discussion of their many problems, to shift the election of officers to the conclusion of the Tuesday morning session.

The talk to be given before the General Luncheon on Tuesday, sponsored, as you will recall, by the Manufacturers' Division, should warrant, and we believe will guarantee, the presence of every person at the convention, for E. A. Tamm, Assistant Director of the Federal Bureau of Investigation will give us an intimate and off the record discussion of "Industrial Sabotage." It has been our pleasure to hear Mr. Tamm on two previous occasions and we can say without reservation of any kind that you will long remember his fascinating story.

Tuesday afternoon has been left entirely free to permit the producers in attendance an opportunity to view in a leisurely way the displays of the Exposition. May we urge that all companies send to the convention their superintendents and operating men as at no other time throughout the year can such a large amount of firsthand information be obtained with such economy of time and expense. Technical advisors of many of the exhibiting companies will be on hand to discuss specific problems with any who may so desire. Members of our Manufacturers' Division go to great length to make their

exhibits interesting and instructive and full advantage should be taken of this opportunity to keep up to date with developments in the machinery and equipment field.

The social highlight of the convention will take place on Tuesday evening when all present will foregather in the headquarters suite at six o'clock for the Presidential Reception, immediately following which the Annual Banquet will take place in the Hall of Mirrors. Dr. R. R. Sayers, newly appointed Director of the U. S. Bureau of Mines, has honored us by accepting our invitation to present the National Crushed Stone Association Safety Awards.

Of paramount interest to the crushed stone industry today is the subject, "Highways and National Defense." It is therefore particularly appropriate that this should be the title of the principal banquet address and that it should be presented by Dr. Miller McClintock of the Yale Bureau for Street Traffic Research who has of late been giving this aspect of highway construction his intensive study.

The Wednesday morning session will open with a talk entitled, "WPA and National Defense," presented by Perry A. Fellows, Assistant Chief Engineer of the Work Projects Administration. Mr. Fellows will be followed by James D. Marshall, Assistant Managing Director of the Associated General Contractors, who will discuss "Contractors and National Defense." Just what the role is of the WPA, originally established as a relief agency, in the governmental construction field, is a matter of much conjecture and it should, therefore, be highly informatory to contrast the governmental viewpoint with that of private industry.

Those who were fortunately able to attend our Annual Convention in St. Louis in 1931, will enthusiastically recall the highly entertaining and instructive dramatic presentation given by Professors Busse and Alvord of New York University, entitled, "How to Win an Argument." A necessary corollary to that important question is "How to Make a Sales Presentation Stay Presented," which will also be given to us in dramatic form by Professor Busse and his present associate, Professor Zink.

This session will be concluded by the report of the Resolutions Committee which in view of the industry's desire to express itself on policies of National importance, will be of more than usual interest.

As previously mentioned, Wednesday afternoon will be devoted to two concurrent group meetings. At the session for operating men the following three main topics will be discussed: "Stockpiling and Reclaiming," "Drilling and Blasting Practices," "Economics and Practicality of Dust Control." These papers will be given respectively by Nelson Severinghaus, Superintendent Consolidated Quarries Corp.; A. J. Cayia, General Superintendent, Inland Lime and Stone Co.; A. G. Seitz, Vice President—Operations, The General Crushed Stone Co. A liberal amount of time has been made available following the presentation of each of these talks for general discussion.

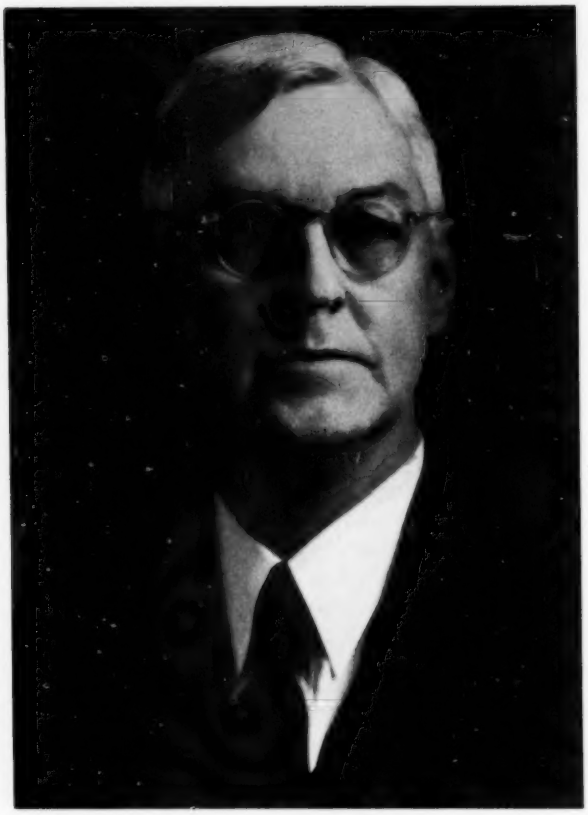
The session for salesmen will open with a talk by F. W. Darner of the Agricultural Adjustment Administration on "AAA Policies with Regard to the Grant-of-Aid Program." This will be followed by a presentation by A. T. Goldbeck, entitled, "How Research Helps Sales." George E. Schaefer will then discuss "Merchandising Crushed Stone," and the concluding paper will be on the subject, "The Salesman's Part in Coordinating Shipments with Plant Production," by Paul R. Anderson of Marble Cliff Quarries. Sufficient time has been allowed following each of these papers for a full round table discussion.

This session will be concluded with a showing of the picture, "Green Pastures," made available through the courtesy of the National Fertilizer Association. This picture constitutes an eloquent argument for the liming of soil and should prove especially interesting to those engaged in the production of agricultural limestone.

Again may we repeat the extreme desirability of companies sending their salesmen and operating men to this convention as they are certain to receive many valuable and profitable suggestions from the papers and discussions which have been scheduled.

With the conclusion of the business session on Wednesday afternoon serious matters will give way to a period of relaxation and enjoyment through the medium of the Convention Cabaret. For this affair a floor show of exceptional character has been obtained and after its presentation the evening will be devoted to dancing and a general good time.

We believe from the foregoing you should have convincing proof that under no circumstances can you afford to be absent from this highly significant meeting of the industry. Matters of vital import to the conduct of your business during the coming year will be discussed and if you are to be adequately prepared to intelligently meet the problems of 1941 you must be with us at Cincinnati.



T. I. WESTON

1881 - 1940

The death of T. I. Weston has saddened our industry. Each of us has lost a truly faithful and loyal friend, a priceless possession. He first became active in the National Crushed Stone Association in 1923 when the Weston & Brooker Company was elected to membership. The value of his counsel and the soundness of his advice soon became evident and in 1927 he was elected Regional Vice-President for the South, as well as a member of the Board of Directors. In 1932 he was elected to the Executive Committee. He held the office of Vice-President until 1937 and remained on the Executive Committee and on the Board of Directors until his death. The recognition of his service to the Association culminated in his election to the Presidency in 1938 and he held this office for two terms until January, 1940.

Mr. Weston was born in Congaree, South Carolina, April 15, 1881, and graduated from The Citadel, the Military College of South Carolina, at Charleston. For some time he practiced Civil Engineering and in 1909 joined with Mr. B. O. Brooker in the Engineering and Contracting firm of Weston and Brooker. In 1912 this firm acquired a quarry at Cayce, South Carolina and in 1930 started a large crushed stone operation at Camak, Ga.

It was through our fellowship with him in the National Crushed Stone Association that those of our industry were enabled to know him best. His quiet and modest dignity, the gentleness of his manner, the very sweetness of his character endeared him to all of us. We admired his intellectual integrity, his ability to think clearly and forcefully, yet with consideration for the opinions of others. To have friends, one must show himself friendly, and "Ike", as we called him, had a host of friends. He was kindly: it is doubtful whether he ever found it in his heart to do an unkindly or hurtful thing. He was loyal: willing to generously sacrifice himself for a friend or a principle. He was dependable: no veering, fitful winds of passing opinion changed the steadiness of his outlook, nor the firmness of his friendship. He was steadfast and true: no one who counted upon his word was in any way misled. He was capable: the reliance placed upon his judgment and executive ability by various industries and organizations, and his many friends throughout the country attest to this fact.

Our hearts will ever be filled with the fragrant memory of his friendship. We will not soon forget the splendid example he so modestly gave us of the value of character and integrity. In the land from which no traveler returns, we know that somehow, in some fashion, he will find opportunities for service beyond the ken of mortal imagination which will bring to him that happiness he so richly deserves.

Designing Concrete Mixtures for Pavements

By W. F. KELLERMANN

Materials Engineer, Division of Tests, Public Roads Administration

• **That the characteristics of aggregates greatly influence the quality of concrete for highways is becoming generally recognized. A method for determining concrete proportions for equal beam strength with different aggregates is described in the present article.**

THE purpose of this report is to describe a method of investigating the flexural strength of concrete in connection with the problem of designing concrete mixtures for pavements and to present the results of a series of laboratory tests which demonstrate how flexural strength may vary over a wide range due to the characteristics of the aggregates employed.

All pavement concrete, particularly that laid in the Northern States, must be designed so as to afford maximum resistance to weathering agencies. Assuming that the constituent materials are durable, it is generally agreed that this may be accomplished either by placing a maximum limit on the water-cement ratio or by requiring a cement content sufficiently high to insure that the maximum allowable water content will not be exceeded. The necessity for limiting the water-cement ratio to insure durability applies to all concrete exposed to the weather.

Insofar as strength characteristics are concerned, concrete for most purposes need only be investigated for compressive strength. However, compressive strength is not of primary importance in concrete for pavement slabs because of the character of the stresses to which such slabs are subjected. Live loads and changes in temperature and moisture, either alone or in combination, produce tensile and flexural stresses which pavements must resist in order to perform the function for which they are designed. Of the two, the flexural stresses are the more important. For this reason, flexural or bending stresses rather than compressive stresses become critical in cases where the concrete mixture is to be designed for use in highway pavements. Therefore the designer of concrete paving mixtures must give consideration not only to the factors that affect durability but also to those variables that affect flexural strength.

Tests Made to Determine Cement Factor for Various Combinations of Aggregates

The specifications for pavement concrete of the American Association of State Highway Officials specify that the proportions shall be based on laboratory tests and shall be such that, in the judgment of the engineer, they will assure durable concrete of the plasticity and workability required, and which will attain at the age of 14 days a modulus of rupture not less than 550 pounds per square inch when tested by the third point method of loading. In order to assure durability it is further specified that the net water-cement ratio shall in no case exceed 0.80 by volume (6.0 gallons per sack of cement).

The tests reported in this paper were made in an investigation of the design of concrete mixtures in which 25 different combinations of fine and coarse aggregate were used, the requirement being compliance with the above specifications. The work was done in the laboratory of the Public Roads Administration during 1936 at the request of the State Highway and Public Works Commission of North Carolina. The purpose was to establish the cement factor required for various combinations of available aggregates, the information thus obtained to be used as the basis for bidding. Seven sands and 13 coarse aggregates, all commercially available in North Carolina, were investigated. The 25 combinations of materials were selected on the basis of economic availability and represented practically all combinations of aggregates that were likely to be encountered in practice in that State.

As will be noted from table 1 the sands varied in grading over a wide range, the fineness modulus of the finest being 2.12 and that of the coarsest, 3.37. All coarse aggregates were separated into three sizes and recombined for test in accordance with the grading shown in table 2, the maximum size being 2 inches. This table also gives the mineral composition of both the fine and coarse aggregates as well as their physical properties. One lot of cement, meeting all A. S. T. M. requirements, was used throughout.

In order to determine the required cement content for each combination of materials it was decided to establish directly the relation between cement content and flexural strength at 14 days, using mixtures with five different cement factors as follows: 4.4, 5.2, 6.0, 6.8, and 7.2 sacks of cement per cubic yard of concrete. This procedure also afforded an opportunity to establish the corresponding relations between water-cement ratio and flexural strength.

The decision to design the mixes on the basis of a fixed cement factor rather than by the use of fixed water-cement ratios was made because of the fact that in the North Carolina specifications the final proportions are stated in terms of a fixed cement factor for each aggregate combination. The problem, therefore, resolved itself into one of designing 125 different concrete mixes: Five cement contents with each of the 25 combinations of aggregates. The problem was complicated by the fact that both angular and rounded coarse aggregates were used in combination with sands graded from extremely fine to extremely coarse.

In keeping with North Carolina practice the different mixes were designed with a view to maintaining a minimum of sand consistent with satisfactory workability at a consistency corresponding to a slump of 2½ inches. This was accomplished by making numerous trial batches, the ratio of fine to coarse aggregate being adjusted, in each case, until, in the opinion of the operator, the minimum sand content was reached.

TABLE 1

SIEVE ANALYSIS OF FINE AGGREGATES FOR CONCRETE MIXES USING NORTH CAROLINA AGGREGATES

Fine aggregate	Percentage retained on sieve no.—						Fineness modulus
	4	8	16	30	50	100	
1	0	0	2.8	35.8	77.3	95.9	2.12
2	0	0	5.3	42.8	79.4	94.4	2.22
3	.5	4.0	19.6	58.0	93.1	99.4	2.75
4	.2	4.1	21.2	63.2	93.2	99.0	2.81
5	0	7.3	26.8	62.1	89.3	97.2	2.83
6	.1	7.1	30.4	68.3	91.0	98.4	2.95
7	.3	14.6	44.2	81.2	97.6	99.4	3.37

The final proportions for each of the 5 cement factors and for each of the 25 aggregate combinations are shown in table 3. This table includes, in addition to the mix proportions by weight, the water-cement ratio by volume, the value of W_c, that is, the volume of water in a unit volume of concrete, the ratio b/b_0 as defined by Talbot and Richart,[1] the mortar voids ratio,[2] the percentage of sand by weight, the fineness modulus of the combined aggregate, and the resulting slump in inches.

Several Theories of Mix Design Tried

In view of the fact that it was necessary to design 25 different mixes for each cement content, attempts were made to apply certain theories of mix design to the problem of determining the proper percentage of sand to use in each case. An attempt to use the fineness modulus theory of Abrams[3] proved unsuccessful due to the fact that a fixed value for maximum permissible fineness modulus could not be used, even in the case of a given sand combined with several coarse aggregates of the same general particle shape.

Next, an attempt was made to design on the basis of a fixed value for the mortar voids ratio, that is, a constant excess of mortar over the amount necessary to fill the voids in the coarse aggregate. This was found satisfactory so long as particle shape remained reasonably constant. However, as will be noted in table 3, a change from angular to rounded coarse aggregate resulted in an increase in the value of this ratio. (Compare combinations 2-4 to 2-9, inclusive, with combinations 2-11 and 2-13.)

This particular difficulty was overcome by using a fixed value of b/b_0 in place of a constant mortar voids ratio. After making many trial batches it was found that, for a given cement content and a given sand, a constant value of b/b_0 could be used irrespective of type of coarse aggregate. (See table 3.) It was noted, furthermore, that certain consistent changes in b/b_0 resulted from changing the cement factor and sand grading. Thus, for a given sand, table 3 shows that an increase in the cement factor of 0.8 sack resulted in a decrease of 0.01 in b/b_0 for equal workability. Furthermore, as the sand used became coarser, it was found necessary to reduce the value of b/b_0. Thus at 6.0 sacks per cubic yard the value of this ratio decreased from 0.90 for sand No. 1 (F. M. = 2.12) to 0.80 for sand No. 7 (F. M. = 3.37).

[1] A. N. Talbot and F. E. Richart, University of Illinois Engineering Experiment Station Bulletin 137. The term b/b_0 is defined as the ratio of the absolute volume of coarse aggregate in a unit volume of concrete (b) to the absolute volume of coarse aggregate in a unit volume of coarse aggregate (b_0). Stated in different terms, it is the apparent volume of coarse aggregate in a unit volume of concrete. The values given in table 3 are on a dry-loose basis.

[2] The ratio of the volume of mortar in a unit volume of concrete to the volume of the voids in the coarse aggregate, determined in a dry-loose condition.

[3] The Design of Concrete Mixtures, by D. A. Abrams. Bulletin No. 1, Structural Materials Research Laboratory, Lewis Institute.

TABLE 2

PHYSICAL PROPERTIES OF AGGREGATES FOR CONCRETE MIXES USING NORTH CAROLINA AGGREGATES

Aggregate	Type	Bulk specific gravity	Weight per cu. ft.[1]		Voids		Absorption	Abrasion loss	
			Dry rodded	Dry loose	Dry rodded	Dry loose		Los Angeles[3]	Deval[3]
			Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
STONE									
1	Dolomite	2.85	105	97	41	45	0.27	30.4	4.3
2	do	2.82	103	93	42	47	.56	33.0	5.0
3	Limestone	2.79	102	92	41	47	.44	21.1	2.6
4	Granite	2.69	101	91	40	46	.46	51.1	4.0
5	do	2.65	102	93	38	44	.46	53.5	2.6
6	do	2.64	102	92	38	44	.58	37.9	2.4
7	do	2.63	100	91	39	44	.52	58.4	3.9
8	do	2.62	95	87	42	47	.28	30.1	2.0
9	do	2.62	100	90	39	45	.44	41.9	3.6
GRAVEL									
10	Gneiss	2.67	106	98	36	41	1.19	47.9	18.5
11	Quartz	2.63	111	103	32	37	.22	53.7	14.6
12	do	2.63	109	103	34	37	.28	40.9	8.2
13	do	2.63	111	104	32	37	.32	54.9	19.4
SAND									
1	Quartz	2.64	98	91	40	45	0.40		
2	do	2.63	100	93	39	43	.50		
3	do	2.63	98	93	40	43	.40		
4	do	2.64	98	92	40	44	.40		
5	do	2.66	103	97	38	42	.35		
6	do	2.64	101	94	39	43	.32		
7	do	2.60	99	94	39	42	.70		

[1] All coarse aggregates proportioned to give following grading in concrete. Unit weights determined for this grading:

	Percent
Total retained on 2-inch sieve	0
Total retained on 1½-inch sieve	15
Total retained on ¾-inch sieve	70
Total retained on No. 4 sieve	100
Fineness modulus	7.75

[2] Grading A used with both stone and gravel.
[3] Grading A used with gravel. Stone sample consisted of 50 pieces weighing 5 kilograms.

It is believed that the systematic variation in b/b_0 with changes in cement content revealed by these tests together with the principle stated by Lyse[4] in 1932 to the effect that, for a given combination of materials and a given consistency, the total quantity of water per unit of volume of concrete (W_c) is constant regardless of the cement content, makes it possible to simplify considerably the problem of designing mixtures of varying cement content. Having established by trial the proper value of b/b_0 to use with given aggregates and with a given cement factor, the proportions required for the same consistency with any other cement factor may be obtained by computation, provided the aggregates have the same gradations as those used in the trial batch. This will be illustrated by an example.

Given a mix having:

The proportions 94:274:492 by weight.
Water-cement ratio 1.01 by volume.
Specific gravities of materials: Cement, 3.16; fine aggregate, 2.66; coarse aggregate, 2.63.

[4] Inge Lyse, Tests of Consistency and Strength of Concrete Having Constant Water Content. Proceedings A. S. T. M., vol. 32, pt. II, 1932.

Percentage of voids in coarse aggregate (dry-loose), 44.5, the corresponding solid volumes per 1-sack batch would be as follows:

		Cu. ft.
Cement	$\frac{94}{62.4\times3.16}$	=0.48
Fine aggregate	$\frac{274}{62.4\times2.66}$	=1.65
Coarse aggregate	$\frac{492}{62.4\times2.63}$	=3.00
Water (W/C)		=1.01
Yield		=6.14

$$\text{Cement factor} = \frac{27}{6.14} = 4.4 \text{ sacks per cubic yard.}$$

$$\text{Bulk volume of coarse aggregate} = \frac{3.00}{1.00-0.445}$$

$= 5.41$ cubic feet.

Then $b/b_0 = \frac{5.41}{6.14} = 0.88.$

Water per unit volume of concrete (W_c) = $\frac{1.01}{6.14} = 0.164.$

Having analyzed the above mix and determined the values of b/b_o and W_c as 0.88 and 0.164, respectively, another mix will be designed with the same materials but with a cement factor of 6.8 sacks of cement per cubic yard of concrete, an increase of 2.4 sacks per cubic yard.

Following the procedure outlined, the value for W_c for the new mix would remain constant at 0.164. The new value for b/b_o is determined as follows: For each increase of 0.8 sack per cubic yard in cement factor, b/b_o is decreased 0.01. Therefore, the new value of b/b_o is $0.88 - \frac{2.4}{0.8} \times 0.01 = 0.85$.

The yield per 1-sack batch for the new mix would be $\frac{27}{6.8} = 3.97$ cubic feet and the apparent or bulk volume of coarse aggregate would be $3.97 \times 0.85 = 3.37$ cubic feet. The corresponding solid volume of coarse aggregate $(b) = 3.37 \times (1 - 0.445) = 1.87$ cubic feet; the solid volume of cement $(c) = 0.48$ cubic feet; and the volume of water $(W/C) = 3.97 \times 0.164 = 0.65$ cubic feet; making a total of 3.00 cubic feet. The only unknown quantity remaining is the volume of fine aggregate, which is determined by subtracting the sum of the solid volumes of coarse

TABLE 3

DATA ON CONCRETE MIXES USING NORTH CAROLINA AGGREGATES

CEMENT FACTOR—6.4 SACKS PER CUBIC YARD

Aggregate: Fine	Aggregate: Coarse	Proportions by weight	Water-cement ratio by volume	W_c[1]	b/b_o	Mortar voids ratio	Sand to total aggregate by weight	Fineness modulus of combined aggregate	Slump
		Pounds					*Percent*		*Inches*
1	1	94:254:548	1.04	0.169	0.920	1.19	31.7	5.88	2.4
	2	94:264:524	1.08	.176	.920	1.18	33.5	5.79	2.3
	3	94:267:519	1.06	.173	.920	1.18	34.0	5.77	2.3
	10	94:226:553	.97	.158	.920	1.21	29.0	6.11	2.5
2	4	94:256:514	1.04	.169	.920	1.19	33.2	5.88	2.5
	5	94:240:526	1.02	.166	.920	1.20	31.3	6.01	2.7
	6	94:245:520	1.01	.164	.920	1.20	32.0	5.98	2.5
	7	94:246:515	1.02	.166	.920	1.20	32.3	5.96	2.4
	8	94:263:492	1.05	.171	.920	1.19	34.8	5.83	2.6
	9	94:251:508	1.02	.166	.920	1.19	33.1	5.93	2.4
	11	94:205:583	.86	.140	.920	1.23	26.0	6.31	2.6
	13	94:200:587	.86	.140	.920	1.24	25.4	6.35	2.5
3	4	94:272:492	1.07	.174	.880	1.30	35.6	5.94	2.4
	5	94:263:501	1.03	.168	.880	1.31	34.4	6.02	2.6
	6	94:263:497	1.04	.169	.880	1.31	34.6	6.02	2.5
	7	94:267:492	1.03	.168	.880	1.31	35.2	5.99	2.4
	9	94:272:486	1.03	.168	.880	1.30	35.9	5.96	2.5
4	13	94:224:550	.95	.155	.860	1.45	28.9	6.32	2.6
5	7	94:274:492	1.01	.164	.880	1.31	35.8	6.00	2.5
	9	94:276:486	1.03	.168	.880	1.30	36.2	5.98	2.5
6	4	94:280:480	1.10	.179	.860	1.36	36.8	5.96	2.4
	6	94:277:486	1.03	.168	.860	1.37	36.3	6.01	2.4
	11	94:237:545	.90	.147	.860	1.44	30.3	6.30	2.6
7	7	94:297:458	1.04	.169	.820	1.50	39.3	6.02	2.3
	12	94:261:519	.89	.145	.820	1.59	33.5	6.27	2.4

[1] Volume of water per unit volume of concrete.

CEMENT FACTOR—5.2 SACKS PER CUBIC YARD

Aggregate: Fine	Aggregate: Coarse	Proportions by weight	Water-cement ratio by volume	W_c[1]	b/b_o	Mortar voids ratio	Sand to total aggregate by weight	Fineness modulus of combined aggregate	Slump
		Pounds					*Percent*		*Inches*
1	1	94:208:459	0.87	0.168	0.910	1.22	31.2	5.90	2.5
	2	94:216:438	.91	.175	.910	1.21	33.0	5.81	2.6
	3	94:217:434	.90	.173	.910	1.21	33.3	5.80	2.5
	10	94:183:463	.82	.158	.910	1.24	28.3	6.15	2.6
2	4	94:207:430	.89	.171	.910	1.22	32.5	5.93	2.6
	5	94:199:438	.85	.164	.910	1.23	31.2	6.02	2.6
	6	94:199:435	.86	.166	.910	1.23	31.4	6.01	2.6
	7	94:202:430	.86	.166	.910	1.22	32.0	5.99	2.5
	8	94:215:410	.89	.171	.910	1.21	34.4	5.85	2.5
	9	94:205:425	.86	.166	.910	1.22	32.5	5.95	2.6
	11	94:169:486	.72	.139	.910	1.27	25.8	6.32	2.5
	13	94:162:491	.73	.141	.910	1.27	24.8	6.37	2.5
3	4	94:225:411	.89	.171	.870	1.32	35.4	5.96	2.5
	5	94:217:420	.85	.164	.870	1.34	34.1	6.04	2.6
	6	94:218:417	.85	.164	.870	1.34	34.3	6.02	2.6
	7	94:218:412	.87	.168	.870	1.33	34.6	6.02	2.5
	9	94:222:407	.87	.168	.870	1.33	35.3	5.99	2.6
4	13	94:184:459	.79	.152	.850	1.48	28.6	6.34	2.6
5	7	94:224:412	.85	.164	.870	1.33	35.2	6.03	2.6
	9	94:224:407	.87	.168	.870	1.33	35.5	6.02	2.6
6	4	94:231:401	.92	.177	.850	1.39	36.6	5.98	2.7
	6	94:224:407	.88	.170	.850	1.40	35.5	6.05	2.6
	11	94:194:455	.76	.146	.850	1.48	29.9	6.31	2.6
7	7	94:243:382	.88	.170	.810	1.53	38.9	6.03	2.5
	12	94:212:433	.76	.146	.810	1.63	32.9	6.30	2.5

CEMENT FACTOR—6.0 SACKS PER CUBIC YARD

1	1	94:173:393	0.76	0.169	0.900	1.24	30.6	5.94	2.5
	2	94:181:377	.78	.173	.900	1.24	32.4	5.84	2.6
	3	94:181:373	.78	.173	.900	1.24	32.7	5.84	2.7
	10	94:153:397	.71	.158	.900	1.27	27.8	6.17	2.6
2	4	94:174:369	.76	.169	.900	1.24	32.3	5.95	2.5
	5	94:162:377	.75	.167	.900	1.25	30.1	6.07	2.6
	6	94:166:372	.75	.167	.900	1.25	30.9	6.04	2.5
	7	94:167:369	.75	.167	.900	1.25	31.2	6.02	2.6
	8	94:181:352	.77	.171	.900	1.24	34.0	5.88	2.5
	9	94:167:365	.77	.171	.900	1.25	31.4	6.01	2.6
	11	94:138:417	.64	.142	.900	1.30	24.9	6.37	2.5
	13	94:133:422	.64	.142	.900	1.30	24.0	6.42	2.4
3	4	94:189:353	.77	.171	.860	1.36	34.9	5.98	2.7
	5	94:182:359	.74	.164	.860	1.37	33.6	6.06	2.7
	6	94:184:356	.74	.164	.860	1.37	34.1	6.04	2.6
	7	94:185:353	.74	.164	.860	1.37	34.4	6.02	2.4
	9	94:187:348	.75	.167	.860	1.36	35.0	6.00	2.7
4	13	94:155:394	.68	.151	.840	1.52	28.2	6.36	2.5
5	7	94:189:353	.73	.162	.860	1.37	34.9	6.04	2.6
	9	94:191:348	.74	.164	.860	1.36	35.4	6.02	2.6
6	4	94:196:344	.78	.173	.840	1.42	36.3	5.99	2.5
	6	94:191:348	.75	.167	.840	1.43	35.4	6.05	2.4
	11	94:165:389	.65	.144	.840	1.51	29.8	6.32	2.3
7	7	94:206:328	.75	.167	.800	1.56	38.6	6.05	2.4
	12	94:178:371	.66	.147	.800	1.67	32.4	6.32	2.5

CEMENT FACTOR—6.8 SACKS PER CUBIC YARD

1	1	94:150:343	0.65	0.164	0.890	1.28	30.4	5.95	2.3
	2	94:156:327	.68	.171	.890	1.26	32.3	5.85	2.6
	3	94:158:324	.67	.169	.890	1.26	32.8	5.84	2.6
	10	94:128:347	.63	.159	.890	1.30	26.9	6.21	2.6
2	4	94:148:321	.68	.171	.890	1.27	31.6	5.98	2.5
	5	94:139:327	.66	.166	.890	1.28	29.8	6.09	2.6
	6	94:143:324	.65	.164	.890	1.28	30.6	6.06	2.5
	7	94:141:322	.67	.169	.890	1.28	30.5	6.06	2.6
	8	94:153:307	.68	.171	.890	1.27	33.3	5.92	2.6
	9	94:144:317	.67	.169	.890	1.28	31.2	6.02	2.6
	11	94:115:364	.57	.144	.890	1.34	24.0	6.42	2.5
	13	94:110:368	.58	.146	.890	1.34	23.0	6.48	2.5
3	4	94:164:307	.66	.166	.850	1.39	34.8	5.98	2.5
	5	94:156:313	.65	.164	.850	1.41	33.3	6.08	2.6
	6	94:159:310	.64	.161	.850	1.40	33.9	6.05	2.5
	7	94:159:307	.65	.164	.850	1.40	34.1	6.04	2.6
	9	94:161:302	.66	.166	.850	1.39	34.8	6.02	2.6

CEMENT FACTOR—6.8 SACKS PER CUBIC YARD—Continued

Aggregate		Proportions by weight	Water-cement ratio by volume	W_c[1]	b/b_0	Mortar voids ratio	Sand to total aggregate by weight	Fineness modulus of combined aggregate	Slump
Fine	Coarse								
		Pounds					*Percent*		*Inches*
4	13	94:130:343	.61	.154	.830	1.55	27.5	6.40	2.6
5	7	94:161:307	.65	.164	.850	1.40	34.4	6.07	2.6
	9	94:164:302	.65	.164	.850	1.39	35.2	6.03	2.7
6	4	94:165:301	.70	.176	.830	1.44	35.4	6.03	2.5
	6	94:161:303	.67	.169	.830	1.46	34.7	6.08	2.6
	11	94:137:340	.59	.149	.830	1.54	28.7	6.38	2.5
7	7	94:178:286	.65	.164	.790	1.59	38.4	6.05	2.5
	12	94:152:323	.58	.146	.790	1.71	32.0	6.34	2.4

CEMENT FACTOR—7.2 SACKS PER CUBIC YARD

1	1	94:137:322	0.63	0.168	0.885	1.28	29.8	5.93	2.6
	2	94:143:308	.65	.173	.885	1.27	31.7	5.88	2.6
	3	94:145:305	.64	.171	.885	1.27	32.2	5.86	2.5
	10	94:119:325	.60	.160	.885	1.31	26.8	6.23	2.6
2	4	94:136:302	.64	.171	.885	1.28	31.1	6.00	2.5
	5	94:128:309	.62	.165	.845	1.30	29.3	6.12	2.5
	6	94:130:306	.62	.165	.885	1.29	29.8	6.10	2.5
	7	94:133:302	.62	.165	.885	1.29	30.6	6.06	2.4
	8	94:141:289	.64	.171	.885	1.28	32.8	5.94	2.4
	9	94:135:290	.62	.165	.885	1.29	31.1	6.04	2.4
	11	94:105:341	.55	.147	.835	1.35	23.5	6.45	2.5
	13	94:102:345	.55	.147	.885	1.35	22.8	6.49	2.4
3	4	94:151:289	.63	.168	.845	1.40	34.3	6.01	2.6
	5	94:144:294	.61	.163	.845	1.42	32.9	6.10	2.6
	6	94:146:292	.61	.163	.845	1.41	33.3	6.08	2.6
	7	94:146:289	.62	.165	.845	1.41	33.6	6.07	2.6
	9	94:149:284	.62	.165	.845	1.41	34.4	6.04	2.6
4	13	94:120:322	.58	.155	.825	1.58	27.1	6.41	2.5
5	7	94:149:289	.61	.163	.845	1.41	34.0	6.09	2.6
	9	94:151:285	.62	.165	.845	1.41	34.6	6.06	2.5
6	4	94:155:290	.66	.176	.825	1.46	35.6	6.02	2.5
	6	94:150:285	.63	.168	.825	1.49	34.5	6.09	2.4
	11	94:127:318	.56	.149	.825	1.57	28.5	6.39	2.5
7	7	94:165:267	.62	.165	.785	1.62	38.2	6.06	2.5
	12	94:141:304	.55	.147	.785	1.74	31.7	6.35	2.5

aggregate, cement, and water from the total yield. Therefore the solid volume of fine aggregate = 3.97 — 3.00 = 0.97 cubic feet. The complete proportions per 1-sack batch for the new mix would be as follows:

	Cu. ft.
Cement (solid)	0.48
Fine aggregate (solid)	0.97
Coarse aggregate (solid)	1.87
Water (W/C)	0.65
Total (solid)	3.97

Multiplying the above by 62.4 times the appropriate values for specific gravity gives the following:

Weight proportions = 94:161:307

W/C = 0.65 (by volume).

Low Water-Cement Ratio Maintained Using Fine Sands

By this procedure any mix, within a reasonable range, can readily be calculated provided the proper values of b/b_0 and W_c have been predetermined on the materials under investigation and, further, provided the slump is to remain constant. As can be seen from the example given above, the only unknown quantity in the mix is the amount of sand and this is determined by simple calculation. In these tests the water-cement ratio determined by calculation from the law of constant water per unit volume of concrete for a constant slump was not always the exact value needed to obtain the proper slump. However, it was possible in all cases to make the proper adjustment by slight changes in the ratio of water to sand, keeping the sum of the absolute volumes of the two ingredients constant. Even though the general law did not hold precisely in all individual cases, that is, to the third decimal, the following tabulation, which gives average values for the 25 combinations, will illustrate its accuracy.

Cement factor, sacks per cubic yard:	W_c
4.4	0.164
5.2	.163
6.0	.163
6.8	.163
7.2	.163

In connection with the procedure employed, that is, the use of the highest value of b/b_0 compatible with workability, it is interesting to note that for a given coarse aggregate and a given cement factor it was possible to use approximately the same water-cement ratio irrespective of whether a coarse or fine sand was used. For instance, in table 3, using a cement factor of 6.0 sacks per cubic yard, coarse aggregate No. 7 was used with sands 2, 3, 5, and 7. These sands varied in fineness modulus from 2.22 to 3.37. However, the total range in water-cement ratio was only 0.02 (from 0.73 to 0.75), demonstrating that, by proper proportioning, it is possible to maintain a low water-cement ratio when using fine sands.

The concrete was mixed in a laboratory mixer of the type shown in figure 1. In order to approximate field conditions, the coarse aggregate was handled in a saturated surface-dry condition and the sand in a wet condition, correction for the free water in the sand being made when computing the water-cement ratio. Test specimens consisted of 6- by 6-inch beams, 21 inches long. In all, 625 specimens—25 combinations of material, times 5 mixes, times 5 specimens per mix made on each of 5 different working days—were fabricated. All strength tests

were made at 14 days, the specimens being tested by the third point method in accordance with A. S. T. M. Method C 78-39. The specimens were placed in the testing machine with the side, as molded, in tension.

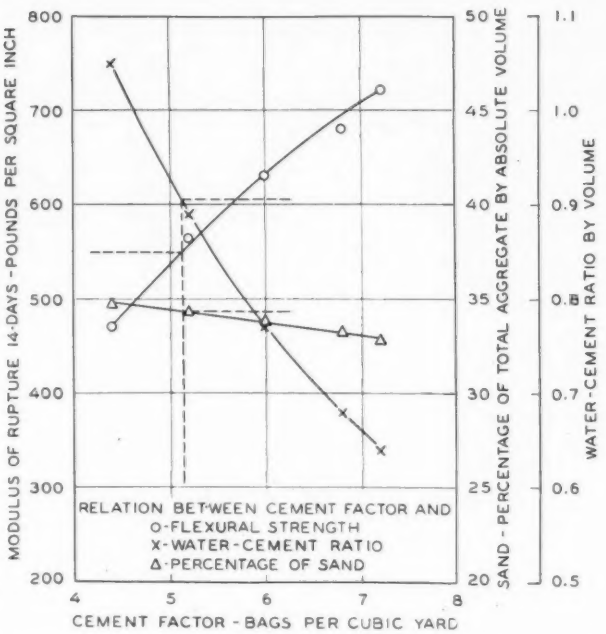
FIGURE 1
Laboratory Mixer Used in Preparing Test Mixtures

The average flexural strengths for each combination of materials for each of the five different proportions are given in table 4. In discussing these results the various combinations of materials will be referred to by number. Thus, combination 2-4 refers to sand No. 2 combined with coarse aggregate No. 4. In order to illustrate the method of plotting the results for the purpose of determining the required cement factor for a specified modulus of rupture, two examples will be given.

Chart Enables Computation of Mix Design

Figure 2 shows a typical chart giving the relations between modulus of rupture and cement factor, water-cement ratio and cement factor, and percentage of sand and cement factor. Considering first the strength-cement factor relationship, it will be noted from the curve that the required amount of cement to produce a modulus of rupture of 550 pounds per square inch was 5.1 sacks per cubic yard. The corresponding water-cement ratio was 0.91 and the percentage of sand 34. From this type of chart a complete mix design could be computed for any strength specified within the range covered. In figure 2 for instance, the range in strength would be from about 500 to 700 pounds per square inch.

Frequently specifications for concrete contain a limiting value for water-cement ratio in order to assure durability. Assuming a maximum allowable value of 6 gallons per sack ($W/C = 0.80$ by volume), it will be observed from figure 2 that the required strength was obtained with a water-cement ratio of 0.91, which is more than allowable. From the water-cement ratio-cement factor curve it is seen that, in order to keep within the limits dictated by durability considerations, it would be necessary to use a cement factor of 5.8 sacks per cubic yard instead



AGGREGATE	NUMBER	TYPE	SP GR	PERCENT ABS.	F.M.
FINE	2	SAND	2.63	0.50	2.22
COARSE	8	GRANITE	2.62	0.28	7.75

FIGURE 2
Concrete Mix Design Chart for Combination 2-8

of 5.1 sacks, the resulting flexural strength being in excess of 600 pounds per square inch.

Figure 3 gives the same type of data for a different combination of materials. The required cement factor as determined from the curve is 5.9 sacks,

with a corresponding water-cement ratio of 0.75. In this case the strength is the governing factor while in the former case the maximum allowable water-cement ratio governs.

Charts similar to figures 2 and 3 were drawn for each of the 25 combinations of materials and the required cement factors obtained from the strength curves as illustrated. These cement factors are enumerated in table 5 and show values ranging from 4.9 sacks for combination 1-1, to 7.1 sacks for combination 1-10, or, for all practical purposes, from 5 to 7 sacks. In view of the fact that the same sand was used in both combinations, the strength differential in this case is a direct function of the concrete-making properties of the two coarse aggregates.

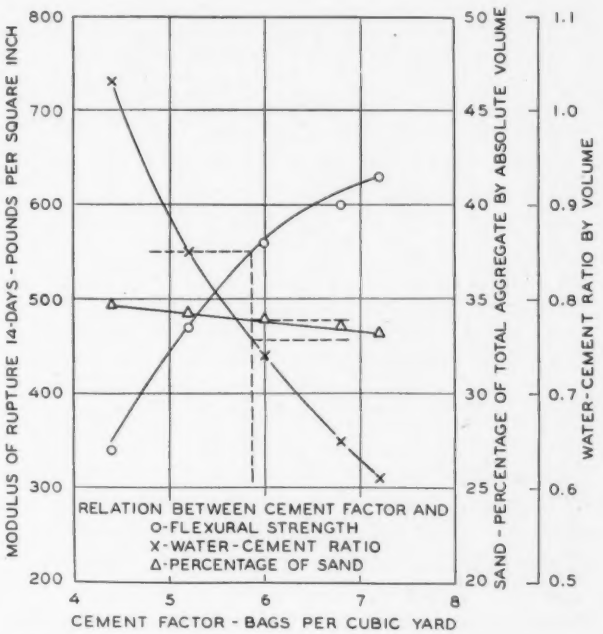
In order to illustrate better the effect of aggregate characteristics upon flexural strength, figure 4 is shown. Three flexural strength-cement factor curves are given, one for combination 1-1, one for combination 1-10, and one for the average of all 25 combinations of materials, thus representing the average and the extreme ranges for the entire series of tests. From the shapes of the two extreme curves it is seen that they tend to converge at the lower cement factors. This is to be expected because of the fact that for very lean mixes the strength of the mortar determines the flexural strength of the concrete. However, as the cement content is increased and the mortar becomes stronger, the quality of the coarse aggregate and the bond between mortar and coarse aggregate become important factors.

TABLE 4

AVERAGE FLEXURAL STRENGTH, 14 DAYS, OF 6- BY 6-INCH BEAMS TESTED ON 18-INCH SPAN WITH THIRD-POINT LOADING, FOR CONCRETE MIXES USING NORTH CAROLINA AGGREGATES

Aggregate		Modulus of rupture [1] for cement factor (sacks per cubic yard) of—				
Fine	Coarse	4.4	5.2	6.0	6.8	7.2
		Lb. per sq. in.	*Lb. per sq. in.*	*Lb. per sq. in.*	*Lb. per sq. in.*	*Lb. per sq. in.*
1	1	470	615	655	795	765
	2	460	575	655	695	755
	3	435	570	715	730	745
	10	380	425	510	535	545
2	4	455	510	540	630	655
	5	430	505	575	635	630
	6	475	570	620	640	615
	7	440	505	555	610	640
	8	470	565	630	680	720
	9	470	565	600	665	680
	11	490	500	545	635	635
	13	430	485	535	560	615
3	4	350	470	570	600	610
	5	340	470	560	600	630
	6	355	470	565	645	630
	7	365	445	575	610	625
	9	390	495	620	665	660
4	13	430	485	510	585	585
5	7	395	490	565	610	670
	9	395	510	615	675	695
6	4	425	490	530	630	620
	6	465	545	585	685	670
	11	480	515	575	635	655
7	7	395	490	565	630	620
	12	505	555	630	675	685
Average		428	513	584	642	654

[1] Each value is average of 5 tests.


MODULUS OF RUPTURE 14-DAYS - POUNDS PER SQUARE INCH
SAND - PERCENTAGE OF TOTAL AGGREGATE BY ABSOLUTE VOLUME
WATER-CEMENT RATIO BY VOLUME
CEMENT FACTOR - BAGS PER CUBIC YARD
RELATION BETWEEN CEMENT FACTOR AND
O-FLEXURAL STRENGTH
X-WATER-CEMENT RATIO
Δ-PERCENTAGE OF SAND

AGGREGATE	NUMBER	TYPE	SP. GR.	PERCENT ABS.	F. M.
FINE	3	SAND	2.63	0.40	2.75
COARSE	5	GRANITE	2.65	0.46	7.75

FIGURE 3

Concrete Mix Design Chart for Combination 3-5

Coarse aggregate number 1 was a dolomite of excellent quality having a surface texture which gave good bond with the mortar. With this aggregate, the full strength of the mortar appeared to have been developed up to a cement factor of 7 sacks per cubic yard. Aggregate number 10 was a structurally weaker material so that the full strength of the mortar was not developed. If the water-cement ratio was the only controlling factor, the strengths of combination 1-10 should have been greater than those developed by combination 1-1 because of the

fact that lower water-cement ratios were used (table 3). Notwithstanding this fact, combination 1-1 gave 26 per cent greater strength for the leanest mix and 44 per cent greater strength for the richest mix.

TABLE 5

CEMENT FACTOR REQUIRED FOR 550 POUNDS PER SQUARE INCH MODULUS OF RUPTURE, THIRD POINT LOADING, FOR CONCRETE MIXES USING NORTH CAROLINA AGGREGATES

Fine aggregate	Coarse aggregate	Cement factor	Fine aggregate	Coarse aggregate	Cement factor
		Sacks per cubic yard			*Sacks per cubic yard*
1	1	4.9	4	13	6.4
	2	5.1			
	3	5.1	5	7	5.9
	10	7.1		9	5.5
2	4	5.8	6	4	6.0
	5	5.7		6	5.3
	6	5.1		11	5.6
	7	6.0			
	8	5.1	7	7	5.9
	9	5.0		12	5.0
	11	5.8			
	13	6.2			
3	4	5.8			
	5	5.9			
	6	5.9			
	7	6.1			
	9	5.5			

At a cement factor of 6 sacks per cubic yard, one commonly used for pavement mixes, combination 1-1 gave 40 per cent greater strength than combination 1-10. While in this particular instance the low strength was probably due to structurally poor material, this is not always the case. Frequently aggregates which are structurally strong give comparatively low flexural strengths in concrete because of the fact that the surface texture does not permit of sufficient bond to develop the full strength of the mortar.

Importance of Determining Flexural Strength of Pavement Concrete Emphasized

Figure 5 shows the strength data given in figure 4 plotted against the water-cement ratio instead of the cement factor. Here again the quality of the coarse aggregate is reflected in the results obtained. Note, for instance, that a water-cement ratio of 0.60 was required to develop a modulus of rupture of 550 pounds per square inch with combination 1-10, whereas this strength was obtained with a water-cement ratio of 0.95 in combination 1-1.

Attention is directed to the fact that the curves for combinations 1-1 and 1-10 are straight lines. However, this was not the case for all combinations of materials investigated, many combinations giving curves which had the characteristic shape of the typical water-cement ratio—compressive strength curve. In fact the average curve shown is of this general shape.

The data shown in figures 2 and 3 might have been plotted with the principal relation between water-cement ratio and strength as in figure 5, with additional curves to give the other desired information. The arrangement of data is of course a matter to be decided by circumstances.

Complete compressive strength data are not available for this series of tests because of the fact that companion compressive strength specimens were not made. However, limited data were obtained for the three leanest mixes (4.4, 5.2, and 6.0 sacks of cement per cubic yard) as the result of tests on modified cubes remaining from the flexure tests.

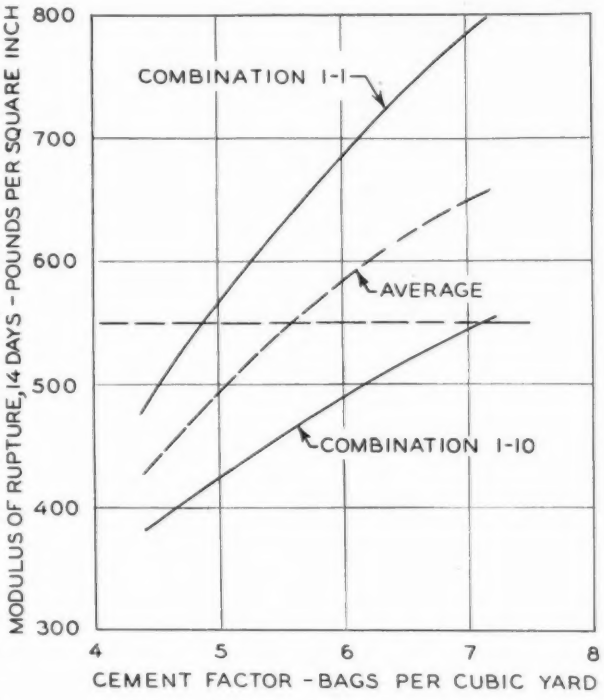


FIGURE 4

Relation Between Cement Factor and Flexural Strength of Concrete (Average Curve and Maximum Range)

These data showed that for combination 1-1 the compressive strengths were 9 per cent greater than those for combination 1-10 as compared with the corresponding average flexural strength differential of 32 per cent.

(*Continued on page 18*)

The 1941 Construction Market

By THOMAS S. HOLDEN

Vice President in Charge of Statistics and Research, F. W. Dodge Corporation, New York City.

• The Defense Program will inescapably exert an important influence upon construction activities for next year. Mr. Holden's observations on this important subject should prove of real interest.

THIS nation is in process of creating a new armament industry, a second navy, training facilities for expanding the army, the navy, and the air force, and housing facilities to accommodate industrial workers and army, navy, and air force personnel. This great program is being superimposed upon the largest physical volume of industrial production we ever had, and the largest private construction volume of post-depression years. The defense program is a rush job.

Since the country has large reservoirs of potential productive capacity, materials, and unemployed man-power, the aim of the government is to turn these surpluses into armaments rather than to sacrifice civilian necessities before we are obliged to do so. It does not appear to be at this time the desire of government officials responsible for defense construction to bring about curtailment of private building and engineering work, but the necessity for speed on defense construction is likely to create in one way or another some interference with the progress of private construction.

The total amount of building and engineering work that can be undertaken and completed in 1941 will depend very much upon the way in which governmental agencies schedule defense construction and announce defense projects to the industry and the way the industry reacts to a sudden but possibly temporary peak volume of activity. The peak load of defense construction, as presently indicated by Congressional authorizations and programs laid out by the War and Navy Departments and the Defense Advisory Commission, will probably occur in the first half of the year; the rate of contract-letting during the second half will, unless additional large defense construction appropriations are made, depend considerably upon whether there will be at that time a strong and effective demand for private construction. Obviously, private construction demand will depend upon the prevailing level of construction costs relative to general commodity prices and living costs.

There is potentially in prospect for next year, in addition to the largest volume of public construction on record, a demand for a considerably increased volume of private construction. The defense construction program, large as it is, represents only a small portion of the whole defense program, which is directed toward the largest industrial production volume this country ever had. The Federal Reserve Board's revised industrial production index averaged 108 in the year 1939 and 121 in 1940. According to reasonable estimates, it will continue on a rising trend through 1941 and will average for the year around 135, an increase for the year of 10 to 12 per cent. This means greatly increased employment, increased purchasing power very widely spread, increased national income. In such an industrially active year, there would naturally be an increased demand for private industrial, commercial, and residential building and for public utility construction.

It seems safe to say that the construction industry, which has not been employed to full capacity at any time during the past ten years, is prepared to handle a considerably larger volume of business than it has had in 1940. Many of the large contracting organizations which are undertaking big defense contracts were comparatively inactive during the first half of 1940, when large public works projects were tapering off and small-type private residential and commercial building were rapidly increasing. Contracts for public ownership projects ran consistently lower than in 1939 during all of the first five months of this year, and at the end of May the cumulative dollar total for the five months was 29 per cent under the figure for the corresponding period of 1939. At the same time, the cumulative total of private contracts was 11 per cent ahead of last year's figure; the largest part of that private volume consisted of one- and two-family houses. By the end of October, thanks to large defense projects, public construction had caught up with last year in dollar volume, and private construction had increased its lead to 17 per cent.

Thus, the first result of letting defense contracts was to reemploy a department of the industry that had been having a slack time. It is also to be noted that the large-scale department of the industry generally employs union labor while the department of small-type buildings employs a great deal of non-union labor. Consequently, the defense construction program at the present moment is bringing about, practically for the first time in post-depression years, full employment of both branches of the industry, and this full employment will continue well into next year. If it were humanly possible to schedule all this increased activity very carefully throughout 1941, it is very likely that the industry could handle a 25 to 33 per cent increase in total volume as compared with this year's activity.

Nevertheless, the rush job of cantonment building, now in progress, is creating unusual and quite sudden demands for materials and building labor. While this rush program is going on, there may be temporary local shortages of certain classes of labor and some difficulties in securing prompt deliveries of materials for private jobs. Some private projects may have to wait. However, if labor, material supply people, builders, and prospective owners can be persuaded to look ahead a few months to the time when the big rush will be over, demoralization of the private building market may be averted. Such a scheduling of activity by general public consent would make government priorities for construction unnecessary. The type of drastic priority regulation that would require a certificate of necessity for private work does not seem likely for 1941.

Already the U. S. Labor Bureau's index of building material prices has risen appreciably, from 93.1 on August 17 to 96.3 on November 16, due principally to increased lumber prices, which passed some weeks ago the previous ten-year peak level of April and May 1937. The index of cost of a frame house increased during the same period by a little more than 7 per cent. Non-union building labor, rapidly acquiring union membership in connection with cantonment jobs, is now being paid at higher rates than it has been accustomed to receive in recent years. This may quite possibly encourage the unions to demand increases as May 1 approaches, the date when most new wage contracts go into effect. In spite of the building cost increases that have taken place, private residential building demand appears to continue strong; the figures for mortgages selected for appraisal and mortgages accepted for insurance by the Federal Housing Administration continue to run ahead of last year.

In the fall of 1939, following the outbreak of the war in Europe, an upward movement in prices was curtailed by a policy of self-restraint in the industry, without the necessity for action by government. Again the price situation will be closely watched during the coming months by industry and government, both of which are more conscious than ever before of the dangers of price inflation. If the situation appears likely to get out of hand, resort may be had to governmental action to prevent runaway prices. If the price situation is kept under reasonable control, as it may be, it will be the first time that such control has operated effectively when a huge armament program or war program was in progress. There is reason to hope, but no absolute certainty, that building costs may not increase at a rate sufficient to discourage private building demand.

It is estimated that defense appropriations and authorizations already made by Congress will provide for approximately $1,880,000,000 of construction in continental United States, this figure excluding any items of land acquisition. Part of this program is already under contract; 15 or 16 per cent of the total will be for projects in the eleven western states, outside the area covered by the F. W. Dodge Corporation's field staff and, therefore, outside the scope of the estimates to be presented later. Defense construction will largely replace the civilian public works programs of recent years. Even the defense housing program cannot be considered as a net addition to the private residential building volume that would normally take place in an industrially active year. While a very strong effort will be made to avoid competition between government housing projects and private residential projects, the demand for speed is likely to cause some defense housing projects to be placed where normal demand might otherwise stimulate an equivalent amount of private work at a somewhat later date.

In view of many critical factors that will be present in the construction market during the early months of 1941, it seems advisable at this time to estimate the year's total construction volume conservatively. At any rate, that is the policy that has been followed by Dodge, which, as an organization, disclaims any ability to predict the future and con-

siders its obligation to the industry, when making advance estimates, to consist in suggesting sound procedure for budgeting sales and production programs. In making estimates, it follows the principle that subsequent adjustment of the figures, if necessary, would preferably be upward rather than downward.

Consequently, while the largest public construction volume on record is anticipated for 1941, and while the potentiality of a very large private building demand is recognized, the estimates here presented indicate only a slight rise in private activity, resulting in an estimated overall increase in dollar volume of combined public and private contracts over 1940 of 14 per cent. Non-residential building is estimated to increase 17 per cent; residential building, 11 per cent; heavy engineering construction, 16 per cent. If this estimated volume is realized, next year's volume will be the largest since 1930; these estimates would not have to be exceeded by a very large margin to produce the largest construction volume since 1929. Any estimates made at this time may very well be subject to considerable revision six months hence; at the end of that period, we shall know a great deal more about the status of private construction demand, about any possible change of the nation's status from that of non-belligerent to active belligerent in the war, about new developments and new appropriations in the defense construction program.

Defense projects will affect the 1941 volume of every general construction classification except religious buildings; there will be even some building of commercial classification types included in defense projects, though fewer proportionally than in other general classifications.

Estimates for the important classes of construction are as follows:

Commercial Buildings: Increased industrial production and employment are practically always accompanied by increased commercial building activity; small new buildings and store modernization projects are again likely to predominate. Dollar volume of contracts for commercial buildings is estimated to increase 16 per cent over 1940.

Manufacturing Buildings: A substantial increase is practically certain, but the amount is difficult to estimate; it has been set at 16 per cent in the Dodge estimate; government contracts, in many instances, will include prices of land acquisition and processing machinery and therefore will be scaled down in amount for inclusion in the construction contract record.

Educational Buildings—Hospitals and Institutions—Public Buildings—Social and Recreational Buildings—Miscellaneous Non-Residential Buildings: Projects for civilian needs likely to be relatively few; defense projects will include buildings in all these classifications; in the aggregate, these classes are estimated to increase about 20 per cent.

Religious Buildings: There is no indication of substantial change in 1941.

Residential Buildings: The estimated 11 per cent increase in total dollar volume over 1940 anticipates that publicly-owned residential building will more than double in dollar volume, and that this increase will be partially but not wholly offset by a moderate decline in private residential building. The estimate anticipates increases in multiple dwellings, in dormitories of the permanent type, and barracks of the temporary type, and in one- and two-family houses. The number of new, combination, and converted family dwelling units built in one-family, two-family, and multiple dwellings are estimated to increase 7 to 10 per cent over 1940. Prefabricated houses are likely to come into the picture in 1941 on a much larger scale than ever before.

Heavy Engineering Construction (Public Works & Utilities): This is estimated to increase 16 per cent in dollar volume. Defense projects will include water-supply, sewerage, airports, and electric power projects; highway construction should continue in large volume.

The overall contract figures for the 37 eastern states covered by the factual field reports of the Dodge organization are an estimated $3,850,000,000 total for the full year 1940 and an estimated $4,400,000,000 total for the full year 1941. In addition to the construction that will take place next year in the territories regularly covered by Dodge, there will also be a large volume of defense construction and private activity in the western states; there will also be defense projects in colonial and insular possessions of the United States and at the new naval and air bases acquired from Great Britain and other countries, which will utilize contracting organizations and labor and materials drawn from the States.

It might not be difficult to build a case for larger 1941 volume than has been here indicated; but, the time to be cautious is when everybody is stepping on the gas; Sunday drivers make the worst traffic jams.

Designing Concrete Mixtures for Pavements

(*Continued from page 14*)

Of the group in which sand No. 2 was combined with eight different coarse aggregates, combination 2-13 gave just about as high compressive strength as any combination in the group. However, it was found that, at a cement factor of 6 sacks per cubic

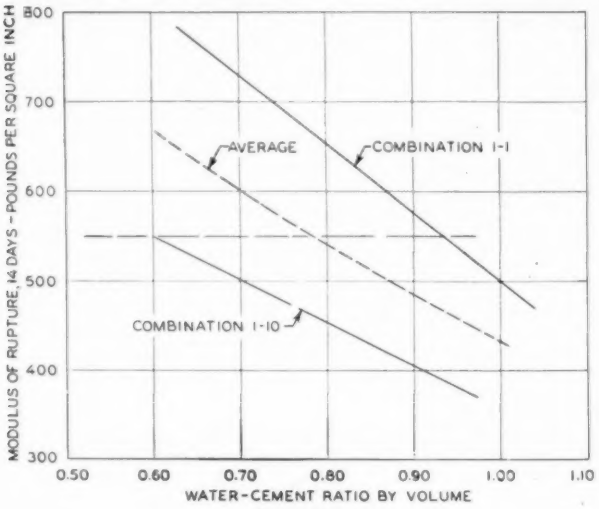


FIGURE 5

Relation Between Water-Cement Ratio and Flexural Strength of Concrete (Average Curve and Maximum Range)

yard, the flexural strength of combination 2-13 was the lowest of all, other combinations in the group giving strengths up to 17 per cent higher than combination 2-13 (table 4). Many other examples could be given to show that two concretes having the same compressive strength do not necessarily have the same flexural strength, emphasizing the importance of determining the flexural strength characteristics of the constituent materials used in pavement concrete.

It is believed that the data presented are sufficient to indicate that, when pavement concrete is to be made of a variety of combinations of aggregates and a reasonably uniform minimum flexural strength is desired, investigations of the materials should be made along the lines indicated in this report in order to predetermine the flexural strengths to be expected. Compressive strength tests on concrete made with the materials to be used are inadequate, as the ratio of flexural to compressive strength varies over wide limits for different combinations of materials.

Highways and National Defense

ALTHOUGH the much discussed report of the Public Roads Administration on the defense highway needs of the nation is yet to be made public, recent statements in Washington have thrown some light on the scope of this study. Details of the highway defense program will not be known until the report is published but it is now apparent that the immediate program of the Administration does not contemplate any large scale construction. Emphasis will be placed on the construction of so-called "access roads" which according to the War Department will require work on approximately 3,000 miles. It is believed that the greater part of this program will be confined to roads in and around the military reservations with a limited amount of construction being carried on in industrial areas.

So far no special defense funds have been made available for a highway program. Present plans apparently contemplate the use of regular highway funds authorized under the Federal Highway Act of 1940. Beginning the first of the year in the neighborhood of $300,000,000 in federal funds will be available for highway construction. This amount includes carryovers from previous authorizations and allocations under the 1940 highway act for the fiscal year 1942. In addition, the W.P.A. will put an undetermined amount into the program under its normal plan of operation together with an amount not to exceed $25,000,000 of W.P.A. funds which may be expended for supervision, equipment and materials in excess of the amounts normally allowed on such projects.

It is difficult to reconcile recent statements by Administration leaders tending to minimize the importance and urgency of defense highway construction with facts made public by the War Department showing the inadequacy of the 75,000 mile system of strategic highways. According to the War Department's figures, 4,000 miles of this system are less than 18 feet in width; 14,000 miles are deficient in road surface strength; 2,400 bridges fall below the standard for strength; and in addition, 500 bridges do not meet the 18 foot standard of width or the 12½ foot standard for clearance. To date no estimate has been given of the amount of funds necessary to bring the defense system up to the required military standards.

However, it may be stated as a certainty that any such scale of highway improvement will require additional funds over those now authorized.

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